A Practical ICT-Based Automated Framework for Sustainable Agricultural Finance and Financial Inclusion in Nigeria

Oluwaseyi Oluwatola Omonijo[1,*], Chinyere Ebirika[2], Oluwatobi Akanbi Johnson[3], Mike Johnson Ugbogbo[4]

[1,2,4]Computer Science Department, Nigeria Maritime University, Okerenkoko, Delta State, Nigeria

[3]Department of ICT & Health Informatics, Federal University of Medicine and Medical Sciences, Abeokuta, Nigeria

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ABSTRACT

Agricultural financing institutions in Nigeria are still structurally fragmented despite growing efforts to promote digital inclusion initiatives. Majority of the existing Agri-Fintech interventions concentrate on digital payments, mobile access or isolated credit analytics; however, they rarely offer an integrated architecture that connects data capture, decision-making automation, secure execution and continuous monitoring. In order to addresses that gap, this study proposed a Design Science-grounded ICT-based automation framework that restructures agricultural financial service delivery as an end-to-end system. Drawing on recent literature, the framework translates documented problem clusters into a five-layer architecture that includes stakeholder data formalization, interoperable ICT integration, embedded decision intelligence, secure transaction execution and adaptive feedback mechanisms. Each layer directly addresses a literature-identified systemic weakness, with explicit traceability between theoretical gaps and architectural components. An illustrative system execution scenario is used to demonstrate operational feasibility and end-to-end process flow. Evaluation results indicate that the framework improves integration, reduces decision time, enhances transaction traceability and supports inclusion in low-connectivity environments. The system reduces information asymmetry and limits fund diversion through controlled execution mechanisms. The framework offers a context-aware blueprint suitable for low-connectivity and high-risk agricultural environments, emphasizing execution integrity, transparency and institutional accountability. Despite being conceptual, the model establishes a systematic framework for prototyping, empirical validation and extendable policy implementation in developing countries.

Keywords: agricultural finance, financial inclusion, ICT in agriculture, digital finance, sustainable finance, rural finance, Nigeria

INTRODUCTION

In Nigeria, agriculture employs a substantial proportion of the workforce and significantly contributes to rural livelihoods and food security. Thereby positioning itself as a central pillar of Nigeria’s economy. However, the agricultural landscape is dominated by smallholder farmers, whose productivity, investment and resilience are still limited by persistent financial constraints (Balana & Oyeyemi, 2022). Traditional agricultural finance mechanisms in Nigeria are characterized by high transaction costs, information asymmetry, weak collateral structures and limited outreach to rural and informal actors, resulting in chronic financial exclusion (Adegbite, 2021; Adesugba & Mavrotas, 2020).

In recent years, the rapid expansion of Information and Communication Technologies (ICT) and digital financial services has generated renewed optimism regarding the transformation of agricultural finance systems in developing economies. According to empirical studies from Nigeria and other Sub-Saharan African nations, the adoption of digital finance is positively correlated with smallholder productivity (Adesiyan, 2025), income development, and value chain participation. In agricultural financing, it is observed that digital platforms, mobile money services, and fintech-enabled microcredit schemes can reduce transaction frictions and partially bridge institutional gaps (Ezeomah, 2021). Recent research has examined both the determinants of digital financial service adoption among smallholder farmers and the use of automation in financial decision making. These studies identified financial literacy (Kolawole et al., 2025), trust, infrastructure availability and socio demographic characteristics as major drivers of digital finance usage (Ogunfolaju et al., 2025) and inclusion outcomes. Other financial technology research emphasized that the potential of automation (Ajuwon et al., 2024), Artificial Intelligence (AI), and data-driven credit scoring (Kowsar, 2022) can help to increase lending efficiency and lessen information asymmetry. Consequently, despite the proliferation of digital finance initiatives, agricultural finance solutions in Nigeria remain technically fragmented at the system level. Existing studies and platforms tend to address isolated functions such as mobile payments, microcredit access, or digital adoption drivers without articulating how these elements can be integrated into a unified, end-to-end automated architecture that supports the full agricultural finance lifecycle (Benni, 2024). Adoption studies are largely descriptive and focus on usage patterns and impact metrics, whereas automation models are typically developed for conventional banking or SME environments. As a result, limited attention is given to how automated credit intelligence, digital access channels and agricultural risk data can be structurally integrated into a scalable system that accounts for climatic volatility, informal production structures and infrastructural constraints in smallholder agriculture in Nigeria.

The absence of a context-aware, ICT-based automated framework that methodically links farmer onboarding, ICT access, intelligent credit assessment, secure transaction execution and continuous monitoring within a single operational system which is designed for low-infrastructure environments is a critical automation-integration gap in the literature. While last-mile connectivity challenges (Umar et al., 2021) and institutional limitations are acknowledged in financial inclusion studies (Croxson et al., 2023), there is limited guidance on how modular technological architectures like multi-channel access interfaces, automated analytics, and traceable transaction mechanisms can be coordinated to provide sustainable agricultural finance at scale in rural Nigeria (Chaudhari et al., 2024).

In order to address this gap, this study adopts Peffers et al., (2007) Design Science Research (DSR) principles to develop a practical ICT-based automated framework conceptualized as a design tool for sustainable agricultural finance and financial inclusion in Nigeria. Instead of focusing solely on adoption outcomes, the study prioritises structural design, process integration, and automation logic, with particular attention to trust, climate sensitivity and infrastructural constraints. In addition to providing a scalable blueprint to guide future implementation, empirical evaluation, and policy-driven digital finance interventions in developing economies, this research adds a system-oriented perspective to the literature on digital agriculture and financial inclusion by proposing a unified, layered framework that connects smallholder agricultural data and formal financial systems.

LITERATURE REVIEW

In developing economies, particularly in Sub-Saharan Africa, sustainable agricultural finance is widely acknowledged as being crucial for alleviating poverty, promoting rural development and ensuring food security. Despite smallholder farmers being the backbone of agricultural production in Nigeria, decades of government intervention and donor-funded initiatives, access to formal financial services remains persistently low (World Bank, 2021). Research indicates that the lack of financial programs is not the cause of this gap, but the structural, informational and institutional weaknesses that limits the effectiveness and sustainability of the existing delivery systems.

The difficulty of identifying and profiling smallholder farmers within official banking systems is one persistent issue in the literature (Aker & Mbiti, 2019). Many maintain informal production and transaction records, operate outside of official registers and lack verifiable identification (IFAD, 2020). Without structured and verifiable data, financial institutions struggle to assess risk, monitor performance or establish institutional trust. This identity gap or mismatch forms a foundational limitation that affects the entire agricultural finance lifecycle. So also, access to digital infrastructure also forms another significant barrier. Although mobile adoption and digital financial services have grown significantly in Nigeria, rural farmers often deal with poor interoperability across digital platforms, inconsistent connectivity and low smartphone ownership (GSMA, 2022). Many digital finance initiatives assume smartphone usage and stable internet access. These assumptions do not reflect rural realities

(Jack & Suri, 2014). As a result, ICT-driven interventions often fail in reaching populations that are financially excluded on a large scale.

These two issues are further compounded by information asymmetry in agricultural credit markets. Due of revenue instability, exposure to climate change and a lack of formal documentation, financial institutions often categorise smallholder agriculture as high risk (Carter et al., 2017). Major components of traditional credit scoring models include formal income records, established banking histories and collateral. Rarely do these criteria fit smallholder brackets. Although recent research demonstrates that alternative data such as farm size, crop cycles and transaction histories can improve risk assessment (Karlan et al., 2020). However, these data are rarely integrated into automated and scalable credit decision systems. As a result, poor financial decisions can be made. Furthermore, this has a high likelihood of cumulating to problem situations that arises after loan approval. Research shows that household pressures, delayed input supply or insufficient monitoring can sometimes cause agricultural loans to be redirected to unproductive uses (Khandker et al., 2016). Manual monitoring approaches are expensive and challenging to maintain in scattered rural populations. These restrictions increase the danger of default, undermine lender confidence and raise moral hazard concerns.

Fintech platforms, donor-funded programs and government efforts usually function independently, each with its own data systems and reporting needs (FAO, 2021). Hence, these different agricultural finance programs are fragmented. Limited interoperability restricts coordinated learning, real time performance tracking and policy adjustment. As a result, lessons learned from earlier initiatives are rarely institutionalised, which leads to recurring inefficiencies.

When all of these gaps are considered collectively, these studies point to a systemic issue rather than isolated operational problems. The recurring issues of identity gaps, infrastructure exclusion, information asymmetry, moral hazard and fragmentation suggest the need for an integrated, automated and system level approach. To ensure that the proposed framework directly responds to documented deficiencies, this study adopts a traceability driven design logic. The proposed ICT-based automated agricultural finance framework's functional layers and technological interventions are mapped to the main issues identified in the literature as shown in Table 1.

Table 1: Literature-Framework Traceability Table

Framework Layer	Systemic Problem Identified in Literature	Literature Support	Framework Intervention
1. Stakeholder and Data Input	Institutional voids and identity gap. Smallholder farmers lack verifiable digital identities and structured records, limiting trust and formal profiling.	Aker & Mbiti (2019); IFAD (2020); Ezeomah (2021)	Integration of NIN linked digital farmer profiles combined with cooperative level validation to establish a trusted digital identity foundation.
2. ICT Access and Integration	Last mile infrastructure exclusion. Limited smartphone ownership, weak connectivity, and poor interoperability restrict rural participation in digital finance systems.	GSMA (2022); Donovan (2018); Jack & Suri (2014); Umar et al. (2021)	Deployment of USSD and SMS interfaces supported by interoperable APIs to enable low bandwidth access across financial institutions and fintech platforms.
3. Automation and Intelligence	Information asymmetry and inappropriate credit scoring models for informal agricultural contexts.	Stiglitz & Weiss (1981); Carter et al. (2017); Karlan et al. (2020); Ajuwon et al. (2024)	AI driven credit scoring that integrates alternative agricultural data such as farm size, crop cycles, satellite indicators, and transaction

			histories for automated risk assessment.
4. Secure Transaction and Execution	Moral hazard and loan diversion. Weak monitoring allows funds to be redirected away from productive agricultural use.	Banerjee et al. (2015); Khandker et al. (2016); Adesugba & Mavrotas (2020)	Conditional or tokenized digital disbursement mechanisms linked to verified input suppliers to ensure funds are used for approved agricultural purposes.
5. Monitoring and Feedback	Fragmentation and weak policy learning. Disconnected programmes limit real time performance tracking and sustainability assessment.	FAO (2021); Benni (2024); Elias et al. (2024)	Real time dashboards and automated feedback triggers that update risk models and generate performance insights for lenders and policymakers.

Table 1 functions as a synthesis mechanism that links theory to design. Each framework layer is grounded in documented empirical challenges and translated into a corresponding ICT enabled intervention. This structured alignment ensures that the proposed framework is not technology driven in abstraction, but problem driven and context responsive to Nigeria's agricultural finance realities.

Research Design and Framework Development

This study adopts a DSR approach to develop an ICT based automated framework for agricultural finance in Nigeria. DSR is well-suited for complex socio technical challenges because it produces and evaluates purposeful results grounded in theory and practice. This study integrates research design with framework development rather than separating methodology from system architecture. This allows the proposed solution to emerge directly from systemic flaws in agricultural finance delivery that have been identified in the literature. The resulting framework, presented in Figure 1, is a unified and layered automated ecosystem that translates documented structural gaps into an operational architecture tailored to Nigeria's low connectivity and high-risk agricultural environment.

METHODOLOGY

Following established DSR guidelines (Peffers et al., 2007), the study progresses through problem identification, requirement synthesis, mode design and analytical evaluation. A systematic review of recent literature on digital agriculture finance, financial inclusion and ICT-enabled automation serves as the foundation for the problem identification. The review consistently identifies five interrelated systemic problems: institutional voids and identity gaps; last mile ICT exclusion; information asymmetry and inappropriate credit scoring models; moral hazard and loan diversion; and fragmentation with weak policy learning.

These documented challenges are translated into explicit design requirements and organized into five corresponding framework layers: stakeholder and data input; ICT access and integration; automation and intelligence; secure transaction and execution; and monitoring and feedback. Table 1 formally documents the traceability between these functional layers and issues identified in the literature.

The result of this process is an evaluation-ready, operationally demonstrable framework that integrates system design, execution logic and measurable performance criteria within a unified architecture.

Phase I: Data Normalization and Gating

The process begins with the conversion of unstructured agricultural activities into structured digital assets. The methodology employs Digital Identity Capture and Multi-Factor Authentication (MFA) tailored to the stakeholder's hardware capability. This phase ensures the "Single Source of Truth" necessary for financial auditing.

Phase II: Hybrid Credit Modeling

Unlike traditional models relying solely on collateral, the proposed methodology utilizes a Hybrid Scoring Approach:

$$Score = \alpha(R_i) + \beta(C_g) + ¥(P_s)$$

Where R_i is individual repayment history, C_g is social collateral and P_s is production stability.

Weights $(\alpha, \beta, ¥)$ are dynamically adjusted based on the feedback loop from Layer 5.

Phase III: Automated Enforcement and Execution

Operational execution is governed by programmatic disbursement. The methodology enforces a "Purpose-Bound Money" approach, where capital is digitally ring-fenced for specific agricultural inputs, validated against the crop cycle identified in Phase I.

Phase IV: Closed-Loop Optimization

The final phase involves Continuous Performance Calibration. The system monitors the Portfolio at Risk (PAR) and Default Clustering. These outputs are not merely reported but are programmatically fed back into the Intelligence Layer to refine future eligibility thresholds.

The methodology ensures that every transaction reinforces the system. A farmer's successful repayment doesn't only just clear their debt, it automatically improves the Reliability Index of their entire process, lowering the barrier for the next applicant. These requirements are operationalised into a conceptual yet structured ICT-based automated architecture during the model design phase. To ensure adaptation across diverse institutional and technological environments, the framework emphasizes modularity, interoperability and rule-based automation.

This methodical process produced the five-layer automated framework illustrated in Figure 1 and described below.

Proposed ICT-Based Automated Framework

The proposed framework is structured as a five-layer automated modular ecosystem that directly addresses to the systemic agricultural finance constraints synthesized in Table 1. Each layer corresponds to a documented problem in the literature and operationalizes a targeted intervention, ensuring a clear traceability between identified gaps and system functionality. The layered architecture separates access mechanisms from core processing logic, thereby enhancing flexibility, interoperability and resilience in low-infrastructure environments. This layered design supports inclusivity while maintaining consistency in data processing, decision-making and execution.

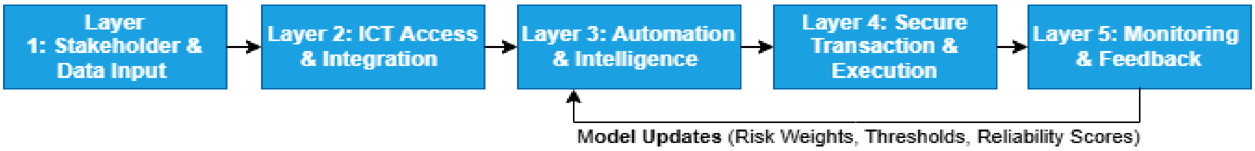

Figure 1: Simplified Flow of the Proposed Multi-Layered Architectural Framework for Automated Agri-Fintech Integration (AAFI) in Nigeria

Figure 1 illustrates a closed-loop automated decision system structured across five interdependent layers. The framework follows a sequential flow from stakeholder data capture to system-wide monitoring, with each layer performing a distinct functional role. Layer 1 structures and validates multi-source farmer and cooperative data into standardized machine-readable formats. Layer 2 enables interoperable access through multi-channel interfaces and API-driven integration with external systems. Layer 3 embeds rule-based and analytical

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intelligence to generate a standardized decision object through automated risk assessment and anomaly detection. Layer 4 translates these decisions into secure and conditional financial execution, incorporating validation, disbursement control and audit mechanisms. Layer 5 evaluates system performance, generates early warning signals, and updates model parameters through a continuous feedback loop that feeds back into the intelligence layer.

This closed-loop configuration ensures traceability, adaptability and scalability, particularly within low-connectivity agricultural finance environments. Figures 2 to 5 provide detailed representations of each layer and their internal functional components.

Stakeholder & Data Input Layer

This layer addresses institutional voids and the identity gap that limit smallholder participation in formal finance systems. Many farmers lack structured production records and verifiable digital identities, as documented in the literature, which makes trust-building and profiling difficult.

To resolve this constraint, the framework integrates structured digital farmer profiles linked to National Identification Systems (NIS) and validated through cooperative level authentication. Core data inputs include farmer identity records, cooperative membership details, farm characteristics, production histories and transaction information. This layer serves as the primary ingestion engine. It establishes a trusted and verifiable data foundation for subsequent credit assessment and monitoring procedures by standardising and digitising these inputs at the entry point through plausibility checks (*FarmSize* X *ExpectedYield*), ensuring that only verified, machine-readable profiles enter the system. This is illustrated in figure 2. Figure 2 captures the operations of both layer 1 and 2.

ICT Access & Integration Layer

This layer responds to the last mile infrastructure gap that excludes rural farmers due to limited smartphone ownership, weak connectivity and poor platform interoperability. Is serves as an abstraction layer that provides channel-agnosticism.

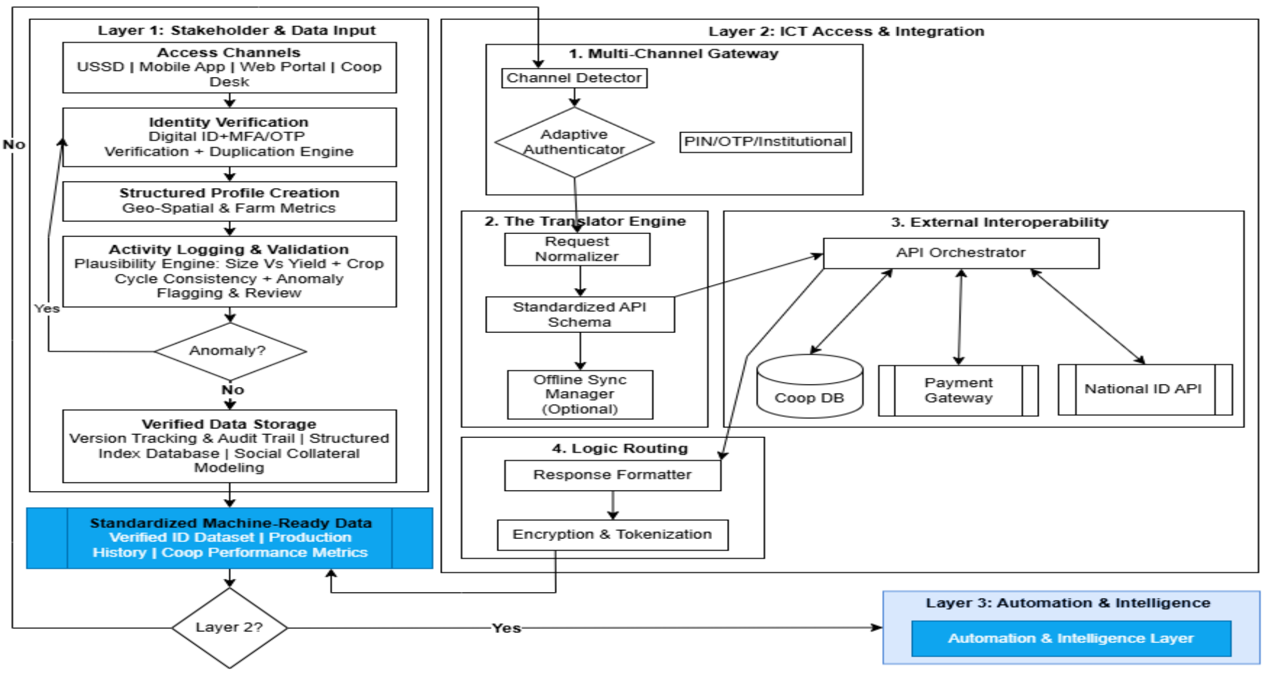

Figure 2: Stakeholder & Data Input Layer and ICT Access & Integration Layer

In addition to mobile and web platforms for users with higher capabilities, the framework allows multi-channel system participation through USSD and SMS interfaces that operate in low bandwidth environments. It translates the heterogeneous inputs (USSD, SMS, Web) into a unified internal API schema, removing device-dependency

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as a barrier to credit. To ensure seamless data exchange, cooperative databases, financial institutions and payment platforms are connected via interoperable application programming interfaces. By separating system participation from smartphone dependency and continuous internet access, this layer guarantee inclusive access across diverse infrastructure conditions.

Automation & Intelligence Layer

This is the computational core layer. Figure 3 shows how this layer targets information asymmetry and the limitations of traditional collateral-based credit scoring models that are unsuitable for informal agricultural processes.

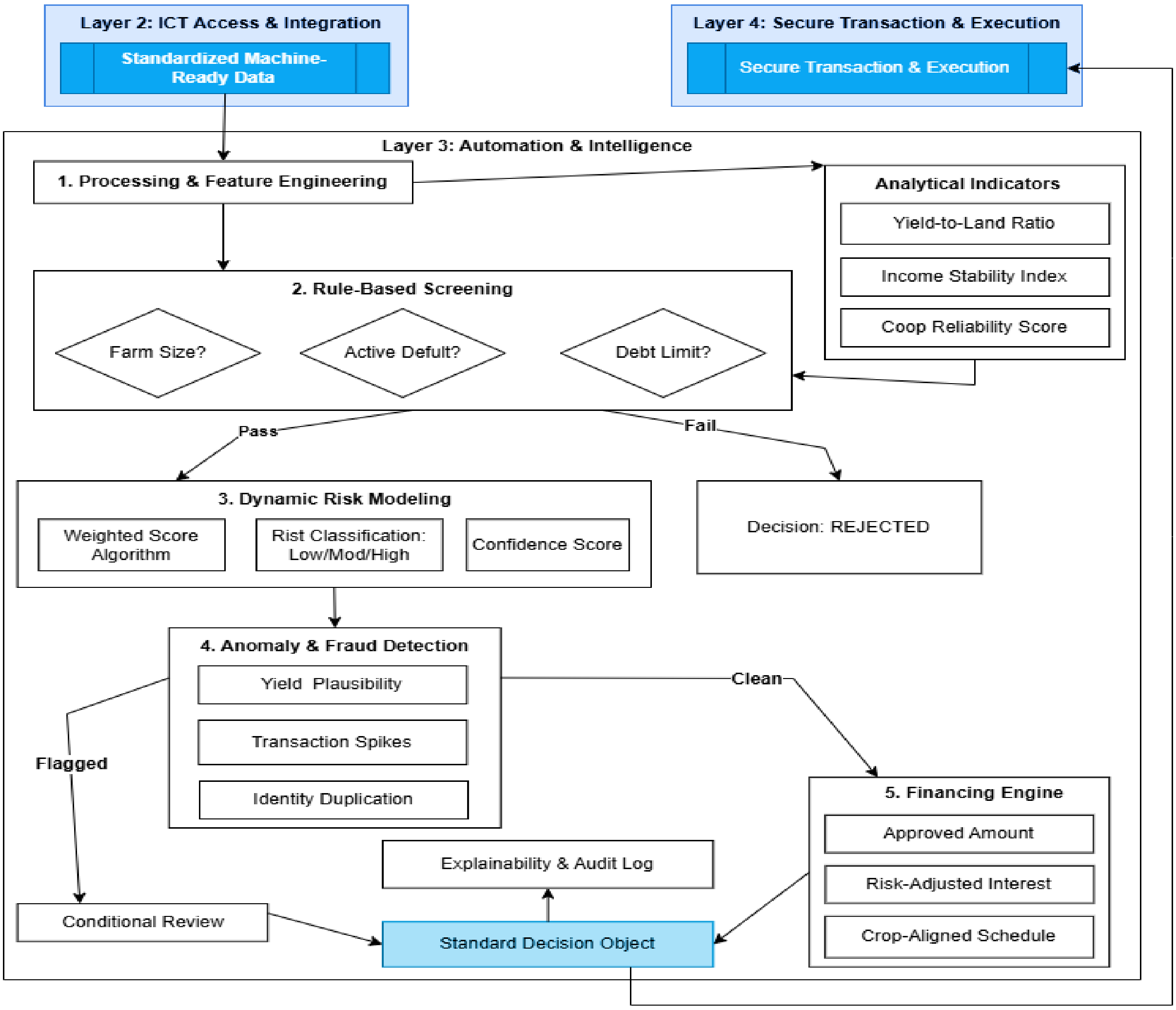

Figure 3: Automation & Intelligence Layer

It utilizes a bifurcated decision logic by first applying deterministic eligibility filters, then executing probabilistic risk-scoring algorithms to generate context-aware financing recommendations. The framework embeds AI driven and rule-based credit assessment mechanisms that integrate alternative agricultural data, including farm size, crop cycles, transaction histories, cooperative performance records and relevant environmental indicators. Automated eligibility screening and risk scoring replace discretionary and static decision processes. This layer converts agricultural data into scalable, consistent, and context-aware financial decisions by embedding intelligence within the system architecture.

Secure Transaction & Execution Layer

This layer plays the role of the enforcement gate. It tackles two persistent weaknesses in agricultural finance delivery systems: moral hazard and loan diversion.

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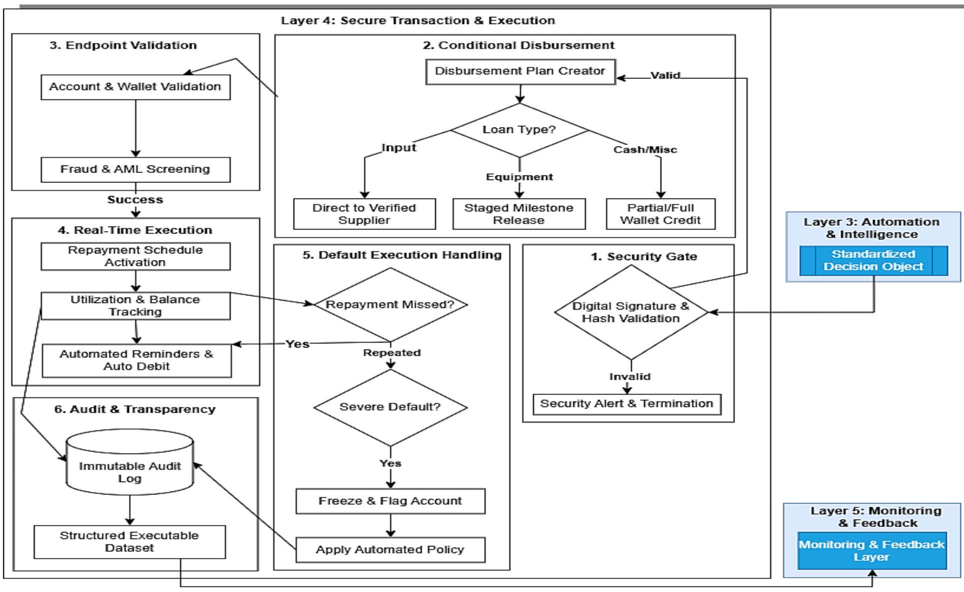

Figure 4: Secure Transaction & Execution Layer

As illustrated in figure 4, approved financing is operationalized through controlled and traceable digital disbursement mechanisms. It transitions the system from "data" to "capital" by utilizing conditional disbursement protocols (e.g., direct-to-supplier transfers), thereby eliminating loan diversion. Tokenised or conditional fund release structures guarantee that loans are allocated to verified agricultural input suppliers or predefined production purposes. Automated repayment scheduling and transaction logging enhance accountability and transparency. By embedding execution controls within the framework, this layer boosts lender confidence and reduces misuse of funds.

Monitoring & Feedback Layer

Figure 5 represents a detailed operation of the monitoring and feedback layer. This layer addresses policy learning gaps and fragmentation across agricultural finance programs. It serves as the self-optimizing "brain" of the system.

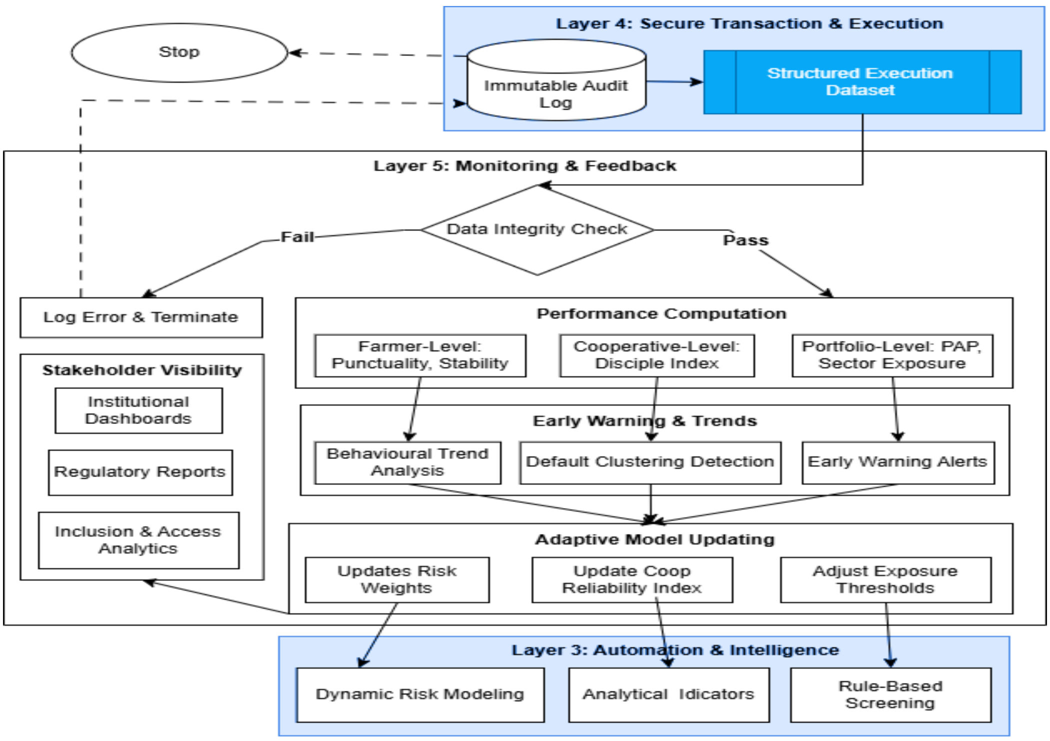

Figure 5: Monitoring & Feedback Layer

Data on loan utilisation, payback patterns and farm-level performance are compiled in real-time dashboards. It monitors real-world repayment outcomes to perform recursive parameter recalibration, updating the risk weights used by Layer 3. Automated feedback triggers update risk models and generate early warning signals based on changing agricultural and environmental conditions. Future credit decisions are improved by feeding performance results back into the automation layer. This closed loop structure transforms the framework into a continuous learning system capable of adaptive and evidence-based decision making.

System Execution Scenario

To demonstrate the operational feasibility of the proposed framework, an illustrative execution scenario is presented to simulate a typical agricultural financing interaction within a low-connectivity environment.

A smallholder farmer initiates a loan request through a USSD interface. Basic data, including identity details, farm size, crop type and cooperative affiliation, are captured within the Stakeholder and Data Input Layer. These inputs are validated against cooperative records and structured into a standardized digital profile.

The validated data are transmitted through the ICT Access and Integration Layer, where they are authenticated and routed via interoperable interfaces. The system ensures accessibility regardless of device capability or network stability.

Within the Automation and Intelligence Layer, the system performs eligibility screening and computes a credit score using predefined rules and contextual indicators. Based on the processed data, the system assigns a risk score and generates a structured decision output specifying loan eligibility, recommended loan size and repayment conditions.

The Secure Transaction and Execution Layer enforces conditional disbursement by routing funds directly to verified agricultural input suppliers rather than to the farmer’s personal account. A repayment schedule is generated, and all transactions are securely logged to ensure traceability.

The Monitoring and Feedback Layer continuously tracks loan utilization and repayment behaviour. Deviations from expected patterns trigger automated alerts, and updated performance data are fed back into the intelligence layer to refine future decision-making.

This execution flow demonstrates how the framework integrates data capture, automated decision-making, controlled financial execution and adaptive learning into a unified system.

Framework Evaluation

The proposed framework is evaluated using a criteria-based conceptual approach grounded in Design Science Research principles. To improve rigor and transparency, evaluation criteria are explicitly aligned with the five architectural layers and supported by measurable indicators derived from the literature and system design objectives.

Table 2: Layer-Aligned Evaluation Criteria and Metrics

Framework Layer	Evaluation Criterion	Metric Indicator	Expected Outcome
Stakeholder & Data Input	Data Integrity	Percentage of verified identities	High accuracy and reduced identity ambiguity
ICT Access & Integration	Accessibility	Availability of USSD, mobile and web channels	Inclusive access in low-connectivity environments (rural inclusion)

ICT Access & Integration	Integration Efficiency	API response time	< 3 seconds latency
Automation & Intelligence	Decision Efficiency (speed)	Time to generate credit decision	< 5 seconds
Automation & Intelligence	Risk Reliability	Consistency of risk classification	Improved predictive accuracy
Secure Transaction & Execution	Transparency	Proportion of traceable transactions	Full auditability (100%)
Secure Transaction & Execution	Fund Control	Percentage of conditional disbursements	Reduced loan diversion
Monitoring & Feedback	Responsiveness	Time to detect anomalies	Near real-time alerts
Monitoring & Feedback	Adaptability	Frequency of model updates	Continuous system improvement

The evaluation demonstrates that each architectural layer satisfies defined performance expectations. By linking criteria to measurable indicators, the framework moves beyond conceptual design to an evaluation-ready system. While empirical validation is outside the scope of this study, the defined metrics provide a clear foundation for future quantitative assessment and implementation.

DISCUSSION AND IMPLICATIONS

This study tackles a structural flaw in Nigeria's agricultural finance ecosystem: while digital inclusion initiatives have increased access, they have not resulted in an integrated system capable of converting data into financial processes that are automated, transparent and executable. Existing Agri-Fintech models typically concentrate on mobile payments, digital onboarding, or standalone credit scoring tools. Although these interventions increase access, they often operate as stand-alone modules. They do not structurally connect stakeholder data capture, interoperability, automated decision logic, secure execution and continuous monitoring within a unified architecture.

The proposed framework advances the discourse by repositioning digital agricultural finance as a system design problem rather than an adoption problem. It begins by formalizing multi-actor data standardization across farmers, cooperatives and financial institutions. The methodology uses structured stakeholder data as the basis for reducing information asymmetry and improving pre-credit risk visibility, rather than treating borrower profiling as a peripheral administrative activity. This directly addresses the fragmented data environments repeatedly identified in earlier studies.

Building on this foundation, the architecture incorporates interoperability and accessibility as fundamental structural principles. Many existing platforms assume reliable connectivity and centralized infrastructure. In contrast, the framework integrates modular APIs, multi-channel access pathways and low-bandwidth compatibility into its design logic. Therefore, ICT integration is treated as a functional condition for inclusive and synchronized service delivery across heterogeneous environments rather than as a technical add-on. The framework then moves to intelligent automation from digitisation. While a number of Agri-Fintech solutions digitally replicate manual appraisal processes, this model incorporates rule-based and knowledge-based decision mechanisms directly into eligibility assessment and risk classification workflows. The shift is significant. Subjective bias is reduced, decision consistency is enhanced and risk evaluation is traceable. Automation restructures the way financial judgement is carried out here and goes beyond simply accelerating processes. Security and execution integrity are positioned as structural layers rather than backend safeguards. The

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operational flow of fund management and credit disbursement integrated auditable transaction logs, role-based permissions and authentication controls. In doing so, the framework directly addresses documented concerns regarding trust deficits, cooperative resource misuse and limited transparency in digitally mediated agricultural finance systems. Therefore, security becomes a functional enabler of institutional legitimacy. Unlike many existing systems that terminate at disbursement, the architecture embeds structured monitoring and feedback loops. The framework is transformed into a continuous learning mechanism by providing functionalities for repayment tracking, performance analytics and adaptive rule recalibration. Financial service delivery is conceptualized as cyclical and data-responsive rather than transactional and static. This dynamic capability strengthens sustainability, especially in environments characterized by erratic climatic patterns and fluctuating market conditions.

This study advances digital agricultural finance from fragmented technological interventions toward an integrated automation architecture. Rather than proposing another access channel, mobile interface, or isolated credit scoring improvement, the framework restructures how financial processes are organized, executed and governed. It establishes a traceable linkage between stakeholder data formalization, interoperable ICT infrastructure, embedded decision intelligence, secure transactional execution and adaptive performance monitoring. This systematic configuration distinguishes the model from other Agri-Fintech approaches that are still functionally fragmented. The alignment between the literature-derived problem clusters summarized in Table 1 and the architectural configuration presented in Figure 1 strengthens the framework's theoretical and structural grounding. Each design layer corresponds to a documented systemic vulnerability. The interdependence among the layers ensures that improvements in access, automation, security, or monitoring do not occur in isolation. Hence, the framework contributes a cohesive socio-technical design logic that connects inclusion, execution integrity and institutional accountability within a single operational continuum.

More importantly, it establishes a structured foundation upon which empirical prototyping, field validation and policy experimentation can be systematically built. This study advances both theory and practice by repositioning agricultural digital finance as an executable system architecture problem instead of a platform deployment. It offers a replicable design blueprint suitable for phased institutional implementation while preserving conceptual coherence.

The practical deployment of the framework requires careful consideration of infrastructural, regulatory and institutional constraints. Limited internet connectivity in rural areas necessitates the use of USSD-based access and asynchronous data processing mechanisms. Regulatory compliance with identity verification and financial standards must be ensured through alignment with national systems and financial authorities.

The modular architecture of the framework enables phased implementation, allowing institutions to deploy core components such as digital identity and basic credit scoring before extending to advanced automation and analytics capabilities. This reduces initial cost and implementation complexity while maintaining system coherence.

Stakeholder adoption remains a critical factor, as trust deficits and varying levels of digital literacy may influence system uptake. Addressing these challenges requires user-centered design, targeted training and institutional incentives.

By explicitly incorporating these constraints, the framework demonstrates practical feasibility and adaptability within real-world agricultural finance environments.

Table 3: Comparative Positioning of the Proposed Framework

Feature	Existing Agri-FinTech Systems	Proposed Framework
System Integration	Fragmented solutions	End-to-end unified architecture
Credit Assessment	Static models	Dynamic, data-driven scoring

Execution Control	Limited enforcement	Conditional and traceable disbursement
Monitoring	Periodic and manual	Real-time automated tracking
Adaptation	Minimal	Continuous feedback-driven learning
Accessibility	Smartphone-dependent	Multi-channel including USSD

CONCLUSION

This study addressed the structural fragmentation of agricultural finance in Nigeria by developing a Design Science-grounded ICT-based automation architecture that integrates stakeholder data formalization, interoperable access, intelligent decision logic, secure execution and adaptive monitoring within a single coherent system. The study reframed agricultural inclusion as an executable system design issue rather than examining digital finance adoption in isolation.

The contribution of this study is threefold. First, it advances scholarship in digital agricultural finance by moving away from modular service interventions and toward an integrated automation-centric architecture. Secondly, it demonstrates how interoperability, embedded intelligence and execution transparency may be structurally aligned with a context-aware blueprint designed for high-risk and low-connectivity environments. Third, by explicitly tracing gaps found in the literature to architectural components, the study strengthens design rigor and provides a replicable model for artefact-based research with respect to developing-countries.

In practical terms, the framework provides policymakers and financial institutions with a modular yet unified reference for structuring scalable digital agricultural finance systems. It prioritises systemic integration over standalone platform development, thereby supporting coordinated and sustainable inclusion policies. The framework remains conceptual and has not undergone empirical deployment. Future research should prioritize prototyping, pilot implementation and quantitative validation of performance, usability and institutional impact. Extensions may incorporate climate risk analytics, real-time agricultural data streams and cross-regional comparative testing to refine adaptability and scalability.

The study demonstrates that sustainable agricultural finance requires integrated automation architectures rather than incremental digitization. It establishes a structured foundation for empirical advancement and policy-oriented system development in ICT-enabled agricultural finance.

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